

जल एवं अपशिष्ट जल के नमूने लेने और  
परीक्षण (भौतिक एवं रसायनिक) की  
पद्धतियाँ

भाग 80 क्लोरीन डाइऑक्साइड

**Methods of Sampling and Test  
(Physical and Chemical) for Water  
and Wastewater**

**Part 80 Chlorine Dioxide**

ICS 13.060.50

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## FOREWORD

This Indian Standard IS 3025 (Part 80) was adopted by the Bureau of Indian Standards, after the draft finalized by the Water Quality Sectional Committee had been approved by the Chemical Division Council.

Chlorine dioxide is a reddish to deep yellowish, volatile, unpleasant smelling gas which is toxic and under certain conditions may react explosively. It should be handled with care in a vented area. Chlorine dioxide is used as bleaching agent in paper and pulp industry and, as antimicrobial agent in food and beverages industry. It is added to water supplies for combating tastes and odors due to phenolic-type wastes, actinomycetes, and algae. It oxidizes soluble iron and manganese to a more soluble form.

The physical and chemical properties of chlorine dioxide are much more similar to that of chlorine in many aspects, hence the method for residual chlorine (IS 3025 Part 26) is recommended before determination of chlorine dioxide.

Under the general title 'Method of sampling and test (physical and chemical) for water and wastewater' IS 3025 has been published in several other parts. This part of IS 3025 covers three test methods for determination of chlorine dioxide in water and wastewater.

In preparation of this standard the considerable assistance has been derived from method no 4500 A, B, C, and E of Methods for the examination of water and wastewater (23rd edition, 2017) published by American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF) jointly.

The composition of the Committee responsible for formulation of this standard is given in Annex A.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'.

*Indian Standard***METHODS OF SAMPLING AND TEST (PHYSICAL AND CHEMICAL) FOR WATER AND WASTEWATER****PART 80 CHLORINE DIOXIDE****1 SCOPE**

This standard (Part 80) describes the following three methods for determination of chlorine dioxide in water and wastewater:

- a) Iodometric method;
- b) Amperometric method I; and
- c) Amperometric method II.

**2 REFERENCES**

The following standards given below contain provisions which through reference in this text constitute provisions of this standard. At the time of publications, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards:

<i>IS No.</i>	<i>Title</i>
IS 7022 (Part I) : 1973	Glossary of terms relating to water, sewage and industrial effluents Part I
IS 7022 (Part II) : 1979	Glossary of terms relating to water, sewage and industrial effluents Part II
IS 17614 (Part 1) : 2021	Water quality — Sampling Part 1 Guidance on the design of sampling programmes and sampling techniques
(Part 3) : 2021	Part 3 Preservation and handling of water samples

**3 TERMINOLOGY**

For the purpose of this standard, the definitions given in IS 7022 (Part 1) and IS 7022 (Part 2) shall apply.

**4 SAMPLING AND STORAGE**

Sampling and sample preservation shall be done as prescribed in IS 17614 (Part 1) and IS 17614 (Part 3). Chlorine dioxide ( $\text{ClO}_2$ ) is to be determined

rapidly after collecting the sample. The sample should not be exposed to sunlight or strong artificial light and do not aerate the mixture. With prior calibration most of the methods can be performed onsite in the laboratory. Minimum  $\text{ClO}_2$  losses occur when the determination is completed immediately at the site of sample collection.

**5 IODOMETRIC METHOD****5.1 Principle**

A pure solution of chlorine dioxide ( $\text{ClO}_2$ ) is prepared by gradual addition of dilute sulphuric acid to a sodium chlorite ( $\text{NaClO}_2$ ) solution. A sodium chlorite scrubber removes contaminants such as chlorine from the gas stream; the gas is passed into distilled water in a steady stream of air.

**CAUTION** – Sodium chlorite should be kept out of direct contact with oxidizable material to avoid possibility of explosion as it is a powerful oxidizer.

**5.2 Interferences**

The strong light and temperature affect solution stability. In order to reduce the  $\text{ClO}_2$  losses stock  $\text{ClO}_2$  solution should be stored in a dark refrigerator.

**5.3 Minimum Detectable Concentration**

One drop (0.05 ml) of 0.01 N (0.01 M)  $\text{Na}_2\text{S}_2\text{O}_3$  is equivalent to 20  $\mu\text{g}$   $\text{ClO}_2$ /l (or 40  $\mu\text{g/l}$  in terms of available chlorine).

**5.4 Reagents**

**5.4.1 Acetic Acid**, concentrated (glacial)

**5.4.2 Potassium Iodide** — crystal

**5.4.3 Standard Sodium Thiosulphate** ( $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ ) — 0.1 N

Dissolve 25 g of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  in 1 000 ml of freshly boiled distilled water and standardize against potassium bi-iodate or potassium dichromate after at least 2 week storage. To allow oxidation of bisulphite, initial storage is necessary. To minimize and avoid bacterial decomposition use boiled distilled water and add a few milliliter chloroform.

Standardize 0.1 N  $\text{Na}_2\text{S}_2\text{O}_3$  by one of the following method:

#### 5.4.3.1 Iodate method

Dissolve 3.249 g potassium bi-iodate or 3.567 g  $\text{KIO}_3$  dried at  $103^\circ\text{C} \pm 2^\circ\text{C}$  for 1 h, in reagent grade water (see IS 1070) and dilute to 1 000 ml to yield a 0.100 0 N solution. Store in a glass-stoppered bottle. With continuous stirring, to 80 ml distilled water add 1 ml concentrated sulphuric acid, 10.00 ml potassium bi-iodate and 1 g KI. Titrate immediately with 0.1 N  $\text{Na}_2\text{S}_2\text{O}_3$  till yellow color of liberated iodine is discharged. Further add 1 ml of starch indicator solution and titrate until blue color disappears.

#### 5.4.3.2 Dichromate method

Dissolve 4.904 g anhydrous potassium dichromate,  $\text{K}_2\text{Cr}_2\text{O}_7$  in a distilled water and dilute to 1 000 ml to yield a 0.100 0 N solution. Store in a glass-stoppered bottle. With continuous stirring, to 80 ml distilled water add 1 ml concentrated sulphuric acid, 10.00 ml of 0.100 0 N potassium dichromate. Let the reaction mixture stand in dark for 6 min before titration. Titrate immediately with 0.1 N  $\text{Na}_2\text{S}_2\text{O}_3$  till yellow color of liberated iodine is discharged. Further add 1 ml of starch indicator solution and titrate until blue color disappears.

#### 5.4.4 Standard Sodium Thiosulphate Titrant — 0.01 N

#### 5.4.5 Standard Starch Indicator Solution

Add little water to 5 g starch (potato, arrowroot) and grind in a mortar to thin a paste. In 1 litre of boiling distilled water pour the mixture and allow it to settle for overnight. Preserve with 1.25 g salicylic acid, 4 g zinc chloride or a combination of 4 g sodium propionate and 2 g sodium azide/1 starch solution.

#### 5.4.6 Standard Iodide — 0.1 N

#### 5.4.7 Dilute Standard Iodide — 0.028 2 N

#### 5.4.8 Stock Chlorine Dioxide Solution

**5.4.8.1** Prepare a gas generating and absorption system. Connect aspirator flask, 500 ml capacity with rubber tubing to a source of purified compressed air. Let the air bubble through a layer of 300 ml distilled water in flask and then pass through 5mm glass tubing into a 1 litre gas generating bottle. The evolved gas is then passed through a scrubber bottled packed with  $\text{NaClO}_2$  solution and finally into a 2 litre borosilicate bottle contacting 1.5 litre distilled water via glass tubing. Air outlet in collecting bottle to allow the air to escape. Select the

gas generating bottle should have wide open mouth to allow insertion of three tubes. First one leading to the bottom for admitting air, second below the liquid level for gradual pouring of sulphuric acid, and last one at the exit to allow the gas generated to escape.

**5.4.8.2** Dissolve 10 g  $\text{NaClO}_2$  in 750 ml distilled water and fill it in 1 litre gas generating bottle. To 18 ml of distilled water add 2 ml concentrated sulphuric acid and mix. Transfer it to funnel. Connect the chlorine dioxide generation and absorption system as mentioned in 5.4.8.1. At the time interval of 5 min add 5 ml of sulphuric acid from funnel. Continue air flow through the system for 30 min till the last portion of acid has been added. Store yellow stock solution in glass stoppered dark color bottle in a dark refrigerator. The concentration of chlorine dioxide thus prepared varies between 250 mg/l to 600 mg/l corresponding to 500 mg/l to 1 200 mg/l of free chlorine.

#### 5.4.9 Chlorine Demand-Free Water

Prepare chlorine demand-free water from deionized water by adding sufficient chlorine to give 5 mg/l of free chlorine. Allow to stand for 2 days to have concentration of 2 mg/l of free chlorine. Remove remaining free chlorine by placing container in sunlight. After several hours take sample and add KI and measure total chlorine with a colorimetric method. Use only after last trace of total and free chlorine has been removed.

Collect the deionized water in a sealed container from which water can be drawn by gravity. Add an sulphuric acid trap consisting of large test tube half filled with 1+1 sulphuric acid connected in series with large empty test tube to the air inlet of the container. Fit both the test tube with stopper. Inlet tube terminates at the bottom and outlet tube terminates near the top of the tube. Connect outlet tube of sulphuric acid trap to deionized water container, connect outlet of empty test tube to inlet tube. The empty test tube prevent discharge of sulphuric acid due to temperature induced pressure changes. The chlorine demand free water stored in such container is stable for weeks unless no bacterial growth occur.

#### 5.4.10 Standard Chlorine Dioxide Solution

Use this solution for preparing temporary chlorine dioxide standards. Dilute required volume of stock chlorine dioxide solution to desired concentration with chlorine demand free water (5.4.9). Standardize solution by titrating with standard 0.01 N sodium thiosulphate titrant in the presence of KI acid and starch indicator.

## 5.5 Procedure

**5.5.1** Select a sample volume which will require no more than 20 ml of 0.01 N sodium thiosulphate (*see 5.4.3*). Thus for residual chlorine concentration of 1 mg/l or less, take 1 000 ml of sample; for range of 1 mg/l to 10 mg/l, a 500 ml of sample and above 10 mg/l proportionately less sample.

**5.5.2** Take appropriate volume of the sample as given in **5.5.1** and add acetic acid to bring down the pH to 3 - 4 in the flask. Add about 1.0 g of potassium iodide crystals and mix with a glass rod. Allow chlorine dioxide to react with acid and KI (*see 5.4.2*) for 5 min before starting titration. Add chlorine-free distilled water if larger volume is preferred for titration. Titrate with 0.01 N sodium thiosulphate (*see 5.4.3*) until yellow colour of the liberated iodine is almost discharged. Add 1.0 ml of starch indicator (*see 5.4.5*) and titrate until the blue colour is discharged. In many cases residual chlorine is very low and starch needs to be added before starting up the titration.

## 5.5.3 Calculation

Concentration of chlorine dioxide, mg/l

$$= \frac{V_1 \times N \times 13.49}{V_2}$$

where

$V_1$  = volume of standard sodium thiosulphate used;

$V_2$  = volume of sample taken for test; and

N = normality of sodium thiosulphate used.

## 6 AMPEROMETRIC METHOD I

### 6.1 Principle

Chlorine dioxide is determined by amperometric titration method which is extension of amperometric method used for determination of chlorine. Chlorine dioxide can be determined by performing four titrations. In first titration chlorine dioxide is oxidized to chlorite and chlorate by addition of sufficient amount of sodium hydroxide to produce the alkaline medium followed by neutralization to a pH 7 and titration of free chlorine. In the second titration, the potassium iodide (KI) solution is added to the sample followed by addition of sufficient amount of sodium hydroxide to produce the alkaline medium followed by neutralization to a pH 7. This titration yields free chlorine and chloramines. In the third titration step further KI solution is added, pH is adjusted to 7 followed by titration of free chlorine, monochloramine, and one fifth of available chlorine dioxide ( $\text{ClO}_2$ ). In the last titration step sufficient

sulphuric acid is added to produce acidic environment, pH 2 so that all available chlorite as well as total free chlorine liberate equivalent amount of iodine from added KI and thus be titrated.

## 6.2 Apparatus

### 6.2.1 Endpoint Detection Apparatus

This apparatus consist of micrometer connected to the cell unit with necessary electrical accessories. The cell units includes noble-metal electrode, a salt bridge which maintain the electrical connection without diffusion of electrolyte and a reference electrode of silver-silver electrode (it may be change based on the given solution) is dipped in a saturated sodium chloride solution and connected into the circuit by means of salt bridge. No foreign matter and deposits on the electrode surface.

### 6.2.2 Agitator

Remove all the chlorine consuming contaminants by thoroughly washing agitator and exposed electrode system with 1 mg/l to 2 mg/l of free chlorine for few minutes. Add potassium iodide to the sample water. Allow agitator and electrode to be dipped in it for 5 min. After that rinse electrode thoroughly with chlorine free water. Now electrode and agitator are ready for use. No iodine reagent to be present in the cell.

### 6.2.3 Burette

### 6.2.4 Glassware

Expose all the glassware to a supply of 10 mg/l of chlorine for 3 h or before use. Then rinse them with chlorine demand free water.

## 6.3 Reagents

### 6.3.1 Standard of Phenylarsine Oxide Solution

— 0.005 64 N

**6.3.1.1** Prepare a solution by dissolving approximately 0.8 g of phenylarsine oxide powder in 150 ml of 0.3 N sodium hydroxide (NaOH). Allow it settle and decant 110 ml into 800 ml of distilled water and mix. With 6 N hydrochloric acid (HCl) bring pH 6 to 7, then dilute it further to 950 ml with the distilled water.

**CAUTION** — Severe poison, cancer suspect agent.

### 6.3.1.2 Standardization

In a flask add 5 ml to 10 ml of freshly standardized 0.028 2 N iodine solution into a flask. Add 1 ml KI solution to the flask. Titrate it with phenylarsine oxide solution (*see 6.3.1.1*) using starch solution

(see 5.4.5) as an indicator. Adjust to 0.005 64 N and recheck against the standard iodide solution (1.00 ml = 200 µg of chlorine).

### 6.3.2 Phosphate Buffer Solution

Dissolve 34.1 g of disodium hydrogen phosphate and 25.4 g of anhydrous potassium dihydrogen phosphate in 800 ml of distilled water. Add 2 ml solution of sodium hypochlorite containing 1 percent chlorine and mix thoroughly. Avoid direct contact with sunlight for 2 days. Then expose it to sunlight or ultraviolet lamp to remove all chlorine present in the solution. Add KI to the solution and measure with one of the colorimetric tests that no total chlorine is present. Dilute it to 1 000 ml and filter if any precipitate is present.

### 6.3.3 Potassium Iodide Solution (KI)

Dissolve 50 g KI and dilute to 1 litre with freshly prepared distilled water. Store it in a dark colored in brown colored bottle in a refrigerator. Discard it when the solution turn yellow.

### 6.3.4 Acetate Buffer Solution — pH 4

In 400 ml distilled water dissolve 146 g anhydrous sodium acetate, now add 480 g of acetic acid. Further dilute to 1 000 ml with chlorine demand-free water.

### 6.3.5 Sodium Hydroxide (NaOH) — 6N (6M)

### 6.3.6 Sulfuric Acid (H<sub>2</sub>SO<sub>4</sub>) — 6N (3M), 1 + 5

## 6.4 Procedure

Effects of pH, time, and temperature of reaction are minimized by standardizing-all conditions.

### 6.4.1 Titration of Free Available Chlorine (Hypochlorite and Hypochlorous Acid)

Sufficient 6M NaOH (see 6.3.5) is added to raise sample pH to 12. After 10 min, 6N H<sub>2</sub>SO<sub>4</sub> (see 6.3.6) is added to lower pH to 7. Thereafter the solution is titrated with standard phenylarsine oxide (see 6.3.1) titrant to the amperometric endpoint. Record result as A.

### 6.4.2 Titration of Free Available Chlorine and Chloramine

Adjust the pH of sample to 12 by adding 6N (6M) NaOH (see 6.3.5). After 10 min the pH of the solution is adjusted to 7, by addition of 6N (3M) H<sub>2</sub>SO<sub>4</sub> (see 6.3.6). Add 1 ml of KI solution (see 6.3.3). Then it is titrated with standard

phenylarsine oxide (see 6.3.1) titrant to the amperometric endpoint. Record result as B.

### 6.4.3 Titration of Free Available Chlorine, Chlorarmine, and fifth of Available ClO<sub>2</sub>

The pH of the sample is adjusted to 7 with phosphate buffer solution, pH 7 (see 6.3.2). Add 1 mL of KI solution (see 6.3.3). Thereafter it is titrated with standard phenylarsine oxide (see 6.3.1) titrant to the amperometric point. Record result as C.

### 6.4.4 Titration of Free Available Chlorine, Chloramines, ClO<sub>2</sub> and Chlorite

To sample add 1 mL of KI solution (see 6.3.3). The pH of the solution is lowered to 2, by adding sufficient amount of 6N (3M) H<sub>2</sub>SO<sub>4</sub> (see 6.3.6). After 10 min, sufficient amount of 6N (6M) NaOH (see 6.3.5) is added to raise pH to 7. It is then titrated with standard phenylarsine oxide (see 6.3.1) titrant to the amperometric endpoint. Record result as D.

## 6.5 Calculation

Convert individual titrations (A, B, C, and D) into chlorine dioxide concentration by the following equation:

$$\text{mg ClO}_2, \text{ as ClO}_2/\text{L} = 1.9 (C - B) \dots \dots (1)$$

$$\text{mg ClO}_2 \text{ as Cl}_2/\text{L} = 5 (C - B) \dots \dots (2)$$

## 7 AMPEROMETRIC METHOD II

### 7.1 Principle

**7.1.1** Amperometric titration II method is carried out similar to amperometric titration I, by successive titration of combinations of chlorine species. The concentration of individual species is determined by calculation. The equilibrium for reduction of chlorine species by iodide is dependent on pH.

**7.1.2** Analyze chlorine, chlorine dioxide, chlorite, and chlorate present in a sample as following steps:

**7.1.2.1** Determine all of the chlorine (free plus combined), and one-fifth of chlorine dioxide at pH 7. Decrease pH of sample to 2, and determine fourth fifth of chlorine dioxide and all the chlorite (includes chlorite present originally in the sample and that formed in first titration). Prepare a second sample by purging with nitrogen to remove chlorine dioxide present and remove remaining chlorine by reacting with iodide at pH 7. Lower pH of latter sample to 2 and determine all the chlorite present. In a third sample, determine all relevant, oxidized chlorine species — chlorine, chlorine dioxide,

chlorite, and chlorate after reduction with hydrochloric acid.

**7.1.3** This method is applicable to concentrated solutions of range 10 mg/l to 100 mg/l and dilute concentration of range 0.1 mg/l to 10 mg/l.

## 7.2 Interferences

The potential for interferences from manganese, copper, and nitrate is minimized by buffering the sample to  $pH \geq 4$ .

## 7.3 Apparatus

### 7.3.1 Titrators — see 6.2

Amperometric titrators with a platinum-platinum electrode are more stable and require less maintenance.

NOTE — Chlorine dioxide may attack adhesives used to connect the platinum plate to the electrode, resulting in poor reading.

### 7.3.2 Glassware

Store glassware to be different from the laboratory glassware as chlorine dioxide react with glass to form hydrophobic surface coating. Immerse all the glassware in a strong chlorine dioxide solution (200 mg/l to 500 mg/l) for 24 h. Then, rinse in water between the use.

### 7.3.3 Sampling

$ClO_2$  is volatile and vaporize easily from aqueous solution. When sampling a liquid stream, contact with air is minimized by placing a flexible sample line to reach the bottom of the sample container, letting several container volumes overflow, slowly removing sample line, and capping container with minimum headspace. The container is protected from sunlight. Sample portions are removed with a volumetric pipet.

## 7.4 Reagents

### 7.4.1 Standard Sodium Thiosulfate — 0.100 N, see 5.4.3

### 7.4.2 Standard Phenylarsine Oxide — 0.005 64 N, see 6.3.1

### 7.4.3 Phosphate Buffer Solution, pH 7 — see 6.3.2

### 7.4.4 Potassium Iodide (KI) — granules

### 7.4.5 Saturated Sodium Phosphate Solution

Prepare a saturated solution of sodium dihydrogen

phosphate with cold deionized-distilled water.

### 7.4.6 Potassium Bromide Solution (KBr) — 5 percent

Dissolve 5.0 g of potassium bromide and dilute to 100 ml. The solution should be stored in brown glass-stoppered bottle. Prepare new every week.

### 7.4.7 Hydrochloric Acid (HCl) — concentrated

### 7.4.8 Hydrochloric Acid — 2.5 N

### 7.4.9 Purge Gas

To purge chlorine dioxide from sample by use nitrogen gas. Check that nitrogen gas is free from contaminants by passing it through 5 percent potassium iodide scrub solution. On first sight of color, discard the solution.

## 7.5 Procedure

Sodium thiosulfate (see 7.4.1) or phenylarsine oxide (see 7.4.2) is used as titrant. The total mass of oxidant species should not be no greater than about 15 mg. Dilute the sample dilutions if necessary. The suitable volume for titration is 200 ml to 300 ml. It is preferred to analyze all samples and blanks in triplicate.

Minimize the effects of pH, time, and temperature of reaction by standardizing all conditions.

### 7.5.1 Titration of Residual Chlorine and One-Fifth of Available $ClO_2$

In a beaker place 1 ml of phosphate buffer, pH 7 (see 7.4.3) and add distilled-deionized water if needed. Sample is introduced with minimum aeration and add 2 g of potassium iodide (see 7.4.4) followed by stirring. Titrate to endpoint. Record the reading as A = ml titrant/ml sample.

### 7.5.2 Titration of Four-Fifths of Available $ClO_2$ , and Chlorite

Continue with same sample, add 2 ml 2.5 N of hydrochloric acid (see 7.4.8). Keep the sample in dark for 5 min. Titrate to endpoint. Record the reading as B = ml titrant/ml sample.

### 7.5.3 Titration of Nonvolatilized Chlorine

In a purge vessel place 1 ml of phosphate buffer, pH 7 (see 7.4.3) and add distilled-deionized water if needed. Add the sample and purge with nitrogen gas (see 7.4.9) for 15 min. A gas-dispersion tube is used to give good gas-liquid contact. Add 1 g potassium iodide (see 7.4.4) and stir. Titrate to endpoint. Record reading as C = ml titrant/ml sample.

#### 7.5.4 Titration of Chlorite

Continue with same sample, add 2 ml 2.5 N of hydrochloric acid (see 7.4.8). Keep the sample in dark for 5 min. Titrate to endpoint. Record the reading as D = ml titrant/ml sample.

#### 7.5.5 Titration of Chlorine, Chlorine Dioxide, Chlorate, and Chlorite

In a 50 ml reaction flask add 1 ml KBr (see 7.4.6) and 10 ml concentrated HCl (see 7.4.8) and mix. Add 15 ml sample is added carefully, with minimum aeration. The solution is mixed and stoppered immediately. Keep it in the dark for 20 min. Rapidly, add 1 g KI granules (see 7.4.4) and shake vigorously for 5 s. Instantly transfer content to titration flask containing 25 ml saturated sodium dihydrogen sulphate solution (see 7.4.5). Reaction flask is rinsed thoroughly and added rinse water to

titration flask. Final titration volume should be about 200 ml to 300 ml. Titrate to endpoint.

7.5.6 Procedure of preceding paragraph is repeated using distilled deionized water in place of sample to determine blank value.

Record reading E = (ml titrant sample – ml titrant blank)/ml sample .....(3)

NOTE — The 15 ml sample volume is diluted appropriately, but maintain the ratio of sample to HCl.

#### 7.6 Calculations

In the following equations, N is the normality of the titrant used in equivalents per litre and A through E are as defined previously

Chlorine dioxide, mg ClO<sub>2</sub> /l

$$= (5/4) \times (B - D) \times N \times 13\ 490 \dots \dots \dots (4)$$

## ANNEX A

(Foreword)

## COMMITTEE COMPOSITION

Water Quality Sectional Committee, CHD 36

<i>Organization</i>	<i>Representative(s)</i>
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*Member Secretary*

MS SHUBHANJALI UMRAO  
SCIENTIST 'B'/ASSISTANT DIRECTOR  
(CHEMICAL), BIS



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### **Amendments Issued Since Publication**

<b>Amend No.</b>	<b>Date of Issue</b>	<b>Text Affected</b>

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